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16. Abstract

Stress and anxiety levels were measured in 10 air traffic control specialists (ATCS) at two low-traffic-density towers, Fayetteville (FYV), Arkansas, and Roswell (ROW), New Mexico, and in 24 flight service (FS) specialists at Oklahoma City (OKC), Oklahoma, Fayetteville, Arkansas, and Roswell, New Mexico. Physiological measurements consisted of heart rate and urine biochemical analysis for 17-ketogenic steroids, epinephrine, and norepinephrine.

On-duty arousal in ATCS's and FS specialists was evident both physiologically and psychologically; such arousal was within psychologically normal limits and was generally low physiologically compared to other air traffic control (ATC) facilities that have been studied in the past. Physiological stress levels at these low-density towers and flight service stations were also low compared to other ATC facilities that were studied previously. It is concluded that it is inappropriate to describe all air traffic control work, as is commonly done in the popular press, as unusually stressful. Such accounts in the popular press tend to deal with the exceptional rather than with the typical controller or facility.

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STRESS IN AIR TRAFFIC PERSONNEL: LOW-DENSITY TOWERS AND FLIGHT SERVICE STATIONS

I. Introduction.

Air traffic control specialists (ATCS) have been extensively studied with regard to the ergonometric, physiological, and psychological demands of their profession; however, as Kalsbeek (1) has pointed out, there is a strong tendency to take measurements only under conditions of overload. This practice has contributed to the popular idea that all air traffic controllers are under a great deal of stress. Sensationalized pseudoscientific reports have reinforced this general concept (2,3,4).

Most air traffic control towers (ATCT) are not high-density facilities. The total number of operations at ATCT's in 1976 ranged from 718,143 at O'Hare to 10,370 at Deadhorse, Alaska (5). More than 50 percent of the total ATCT operations took place at 27 percent of the ATCT's. Sixty-two percent of the ATCT's had less than 100,000 operations in 1976 (5); thus, most are not high-density facilities, and any generalization about stress in ATCT's must take that fact into account. Total operations and national ranking for the facilities in the study reported here are shown in Table 1.

In his presentation of a paper in 1976 (1), Kalsbeek represented stress versus load in ATCT's as theoretically conforming to a U-shaped curve (Fig. 1). There are considerably more data related to Kalsbeek's zone of overload than there are to the zone of underload; yet this condition of low-level activity characterizes work on the mid shift at some air traffic control (ATC) facilities and virtually all work at others where traffic volume is low.

Eleven studies at eight ATC facilities have been carried out in previous years by this laboratory in an attempt to provide a general characterization of stress associated with ATC work. All these studies have been conducted at high- or medium-density facilities. To describe stress in terminal ATCS's equitably, however, it is necessary to include representation from ATCT's of various levels of activity. Towers at Drake Field in Fayetteville, Arkansas, and Industrial Air Center in Roswell, New Mexico, were selected as sites for the present study to provide data from low-density terminal facilities and thus complete the spectrum of levels of tower workload.

TABLE 1. Total Operations and National Ranking of OKC, FYV, and ROW FSS's and ATCT's in 1976 (5)

Facility	Total Operations	National Ranking
OKC FSS	425,582*	40**
FYV FSS	95,490*	226
ROW FSS	75,028*	256
ROW ATCT	93,296	275***
FYV ATCT	39,722	404

* Includes telephone and face-to-face weather briefings as well as radio callups.

** Total U.S. FSS's: 347

*** Total U.S. ATCT's: 424

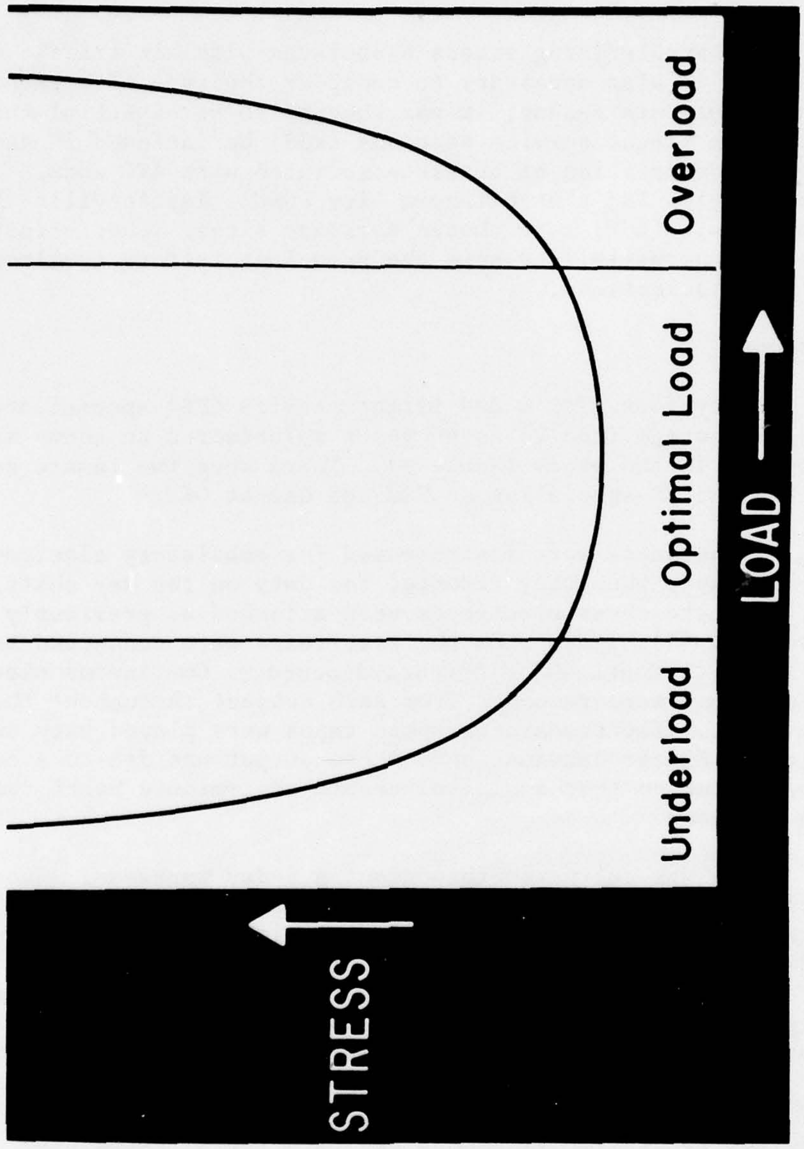

Figure 1. Theoretical curve relating the stress response to load (1).

In characterizing stress associated with air traffic control, it is also necessary to consider the type of work being done. For this reason, it was thought to be essential that data from flight service stations (FSS) be included in any general description of stress associated with ATC work. Accordingly, FSS's at Oklahoma City (OKC), Fayetteville (FYV), and Roswell (ROW) were chosen as study sites. Cost effectiveness and accessibility were the principal factors involved in these selections.

II. Methods.

Thirty-four ATCS's and flight service (FS) specialists ranging in age from 23 to 60 years volunteered to serve as subjects in the study (Table 2). There were two female subjects--one FS specialist at ROW and one at OKC.

All subjects were instrumented for ambulatory electrocardiography when they reported for duty on the day shift. Silver-paste chest electrodes were attached as previously described (6); leads from the electrodes were connected to an Avionics Model 400 Electrocardiocorder. Continuous electrocardiograms were recorded from each subject throughout the day shift. Electrocardiographic tapes were played back on an Avionics Electrocardioscanner whose output was fed to a counter and printer so that a digital record of 1-minute heart rates was produced.

Urine was collected throughout a 5-day workweek. Two pooled specimens/day were collected representing (i) the 8-h work day, and (ii) the night sleep period. Collections were made into 1-qt screw-capped plastic bottles containing an excess of dry boric acid as a preservative. Specimens were logged and immediately placed in a freezer, where they were kept frozen until thawed for analysis. The specimen consisting of urine formed during night sleep was used for resting values. Subjects brought this night sleep specimen with them when they reported for duty. Urine was analyzed for 17-ketogenic steroids (17-KGS), epinephrine, norepinephrine, and creatinine as previously described (7). Values are expressed as weight per 100 mg creatinine.

The State-Trait Anxiety Inventory (STAI) (8) was used to measure the psychological arousal of the participants. Each subject completed the A-State scale of the STAI as a measure

TABLE 2. Urinary Metabolite Excretion Data μg/100 mg Creatinine

		17-KGS			Epinephrine			Norepinephrine		
Facility	No.	Rest	Work	P*	Rest	Work	P*	Rest	Work	P*
OKC FSS	13	423.10	713.00	0.01	0.56	1.17	0.01	2.29	3.37	0.01
FYV FSS	8	414.70	608.30	0.01	0.57	1.05	0.01	2.10	2.52	0.05
ROW FSS	3	500.80	718.50	NS	0.67	1.30	NS	3.05	4.55	NS
FYV ATCT	4	551.70	807.90	NS	0.53	0.86	0.01	1.97	2.14	NS
ROW ATCT	6	526.40	829.00	0.05	0.66	1.03	0.05	2.26	2.60	NS

* Paired t-test

of current arousal or anxiety level immediately before and after each work day. The general propensity of the individuals to experience anxiety, as reflected in their reports of typical arousal levels, was measured by the A-Trait scale of the STAI just before the initial shift of the study.

III. Results.

Heart Rate. Mean heart rates at the several facilities are shown in Table 3. The only statistically significant change ($p < .01$) in heart rate from before-duty to on-duty conditions occurred at ROW FSS, where the mean rate decreased by 11 beats per minute.

TABLE 3. Mean Heart Rates at the Several Facilities

	MEAN HEART RATE (bpm ± SEM)		
Facility	Before duty	On duty	P
OKC FSS	80 ± 1	82 ± 1	NS
ROW FSS	98 ± 5	87 ± 2	0.01
FYV FSS	84 ± 2	80 ± 3	NS
ROW ATCT	92 ± 4	85 ± 2	NS
FYV ATCT	79 ± 1	73 ± 4	NS

Urine Chemistry. Excretion values for the three metabolites under resting and working conditions at the five facilities are shown in Table 2. It is evident from these data that there are consistent duty-related increases in all three urinary excretion products; some of the increases achieved statistical significance at OKC and FYV FSS's and at FYV and ROW ATCT's.

A comparison of these facilities with others by means of a stress index (9) is shown in Table 4. This ranking by composite stress index (C_s) shows that OKC FSS, FYV FSS and ATCT, and ROW ATCT are positioned at the low end of the stress spectrum. The position of ROW FSS in the ranking must be interpreted with the knowledge that only three FS specialists participated at that facility and that the relatively high C_s for ROW was caused by the copious excretion of all three stress indicators by only one of the subjects.

The values in Table 4 are shown graphically in Figure 2. In this diagram, the values of c_{st}, c_e, and c_{ne} are presented as vectors. Lines perpendicular to the ends of the vectors form an equilateral triangle whose altitude is equal to the sum of the vectors; therefore, the area of the triangle is proportional to C_s (the average of c_{st}, c_e, and c_{ne}). The area of the triangle thus represents total stress, and the relative contributions of effluents from adrenal cortex, adrenal medulla, and sympathetic nervous system can be ascertained from the lengths of the internal lines. This diagram was first used by Otto Streng to show the relationship of three isoagglutinins (10).

State-Trait Anxiety Inventory. The mean A-Trait scores for the two groups of participants differed significantly ($p < .05$) with the FSS group showing a tendency toward higher scores (Table 5). By using collegiate undergraduate normative data, we determined that the mean FSS score falls at the 36th percentile, while the mean ATCT score falls at the 14th percentile. In terms of A-Trait data taken from past studies of controllers (11,12,13,14), the mean for the FSS group falls approximately at the 70th percentile of all previously studied controllers, while the mean for the present ATCT group falls at the 45th percentile. In other words, these FSS personnel score high relative to other controllers in proneness to anxiety arousal, while the individuals in the present ATCT group have an average level of anxiety proneness for controllers.

The difference between the two groups on the A-Trait scale was also noted in the A-State scale scores (Table 5). Both before-shift and after-shift A-State scores were significantly ($p < .05$) higher for the FSS than for the ATCT group.

TABLE 4. Comparison of Various ATC Facilities by Means of a Stress Index

Facility	C_s	c_{st}	c_e	c_{ne}
O'Hare ATCT ('68)	1.05	1.41	0.75	0.98
Opa Locka ATCT ('72)	0.84	0.64	0.74	1.15
Atlanta ARTCC ('73)	0.82	0.76	0.34	1.37
Miami ARTCC ('72)	0.76	0.61	0.71	0.96
Los Angeles TRACON ('74)	0.75	0.27	1.10	1.44
Houston ATCT ('70)	0.74	1.27	0.29	0.65
Roswell FSS ('76)	0.73	0.40	0.69	1.10
Oakland TRACON ('74)	0.72	0.23	1.31	0.61
Houston ATCT ('71)	0.68	0.89	0.62	0.52
Oakland TRACON ('72)	0.60	0.62	0.76	0.43
Los Angeles TRACON ('72)	0.60	0.66	0.34	0.81
Roswell ATCT ('76)	0.49	0.45	0.50	0.50
Oklahoma City FSS ('76)	0.47	0.33	0.49	0.59
Fayetteville ATCT ('76)	0.40	0.49	0.36	0.34
Fayetteville FSS ('76)	0.39	0.28	0.46	0.42
Fort Worth ARTCC ('73)	0.34	0.22	0.58	0.20

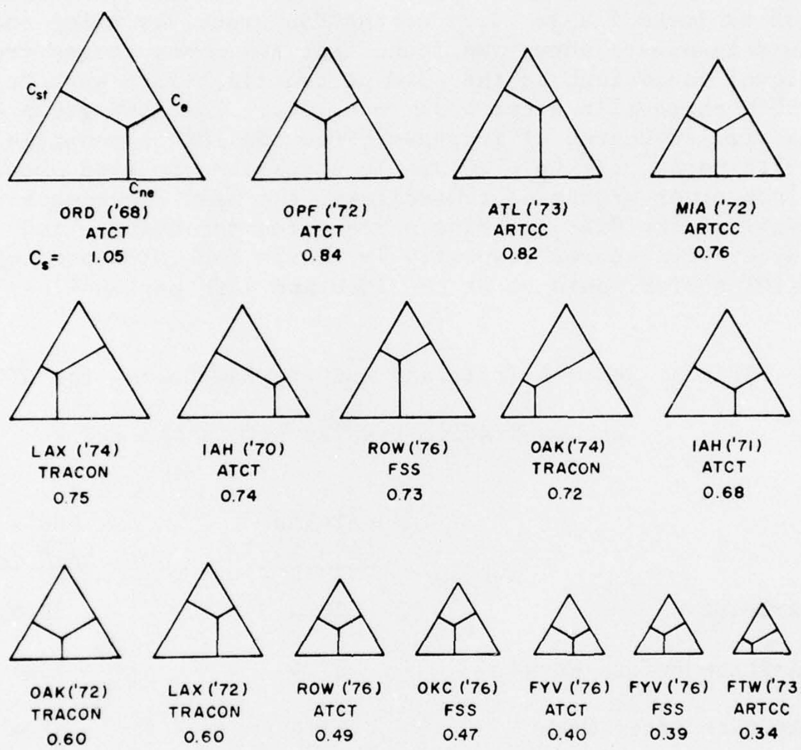

Figure 2. Stress at various ATC facilities represented on Streng diagrams.

However, if the A-State scores are adjusted for the difference in mean A-Trait scores, the differences in A-State scores become statistically negligible.

In most of the previous studies of psychological arousal in air traffic controllers, there has been an increase in A-State scores from before to after work shifts (11,12,13). In the present study, a like increase was found for both groups of subjects (Table 5). For the FSS group, by using college undergraduate norms, we found that the means ranged from a level equivalent to the 43rd percentile before work to the 59th percentile after work ($\underline{p} < .01$). The ATCT group showed a similar degree of increase, from the 18th percentile to the 35th percentile ($\underline{p} < .01$). In comparison to data obtained from other groups of controllers, the mean FSS scores would fall at the 61st and 81st percentiles for before- and after-work scores respectively, while the corresponding mean ATCT scores would be at the 18th and 44th percentiles.

TABLE 5. Mean A-Trait and A-State Raw Scores for ATCS's at Low-Traffic-Density ATCT's and FSS's

	ATCT's (n = 10)	FSS's (n = 25)
A-Trait	28.0	32.6
A-State Before Work	27.4	33.4
A-State After Work	31.4	37.4

IV. Discussion.

Taken in the aggregate, urinary and heart rate data indicate that work at these FSS's and ATCT's is relatively low in stress content. On-duty arousal is evidenced by an increase in urinary output of all metabolites, but this increase is either less or no greater than that at busier facilities. (See Table 6 for rankings of ATC facilities according to the extent of biochemical arousal.)

TABLE 6. Ranking of Facilities in Decreasing Order of On-Duty Arousal as Indicated by Urinary Metabolites

Ranking	17-KGS	Epinephrine	Norepinephrine
1	FTW ARTCC ('73)	IAH ATCT ('70)	OPF ATCT ('72)
2	ATL ARTCC ('73)	OPF ATCT ('72)	LAX TRACON ('72)
3	LAX TRACON ('72)	MIA ARTCC ('72)	MIA ARTCC ('72)
4	OAK TRACON ('74)	OAK TRACON ('72)	FTW ARTCC ('73)
5	OPF ATCT ('72)	FTW ARTCC ('73)	ORD ATCT ('68)
6	OAK TRACON ('72)	LAX TRACON ('72)	ATL ARTCC ('73)
7	LAX TRACON ('74)	ATL ARTCC ('73)	LAX TRACON ('74)
8	MIA ARTCC ('72)	OAK TRACON ('74)	OAK TRACON ('72)
9	IAH ATCT ('70)	ORD ATCT ('68)	IAH ATCT ('70)
10	OKC FSS ('76)	LAX TRACON ('74)	OAK TRACON ('74)
11	ROW ATCT ('76)	IAH ATCT ('71)	ROW FSS ('76)
12	FYV FSS ('76)	FYV ATCT ('76)	FYV ATCT ('76)
13	FYV ATCT ('76)	OKC FSS ('76)	OKC FSS ('76)
14	ROW FSS ('76)	ROW FSS ('76)	IAH ATCT ('71)
15	IAH ATCT ('71)	FYV FSS ('76)	FYV FSS ('76)
16	ORD ATCT ('68)	ROW ATCT ('76)	ROW ATCT ('76)

Figure 3 is a graph of resting and working levels of epinephrine excretion at six ATCT's versus annual traffic counts at the times the studies were conducted. The relationship for the working values is significant (R = 0.96) with O'Hare being the exception. However, it should be pointed out that work at O'Hare was divided, with separate cab control positions for the north and south sides of the airport; one side of the airport was customarily used for departures and the other for arrivals, thus the work was about equally divided between the two sides. Two radar approach and two departure control positions also reduced the traffic load impinging on each controller. If the traffic count at O'Hare is halved to reflect the fact that only half the traffic load impinged on each controller, then the epinephrine excretion value for O'Hare controllers falls near the line of best fit for the other ATCT's. Epinephrine excretion therefore appears to be the best indicator of responsiveness to work involving direct control of aircraft. This finding confirms an earlier observation at Opa Locka ATCT, where a strong correlation was found between radio communication time and epinephrine excretion (9). Resting values showed no such relationship.

As expected from past observations, excretion values for norepinephrine and 17-ketogenic steroids are not so clearly related to traffic count as is epinephrine excretion. Steroid excretion at FYV and ROW ATCT's is lower than at other ATCT's that have been studied. Norepinephrine excretion is lower at ROW than at other ATCT's, but it is as high at FYV as at Opa Locka and O'Hare. These two metabolites are reported to reflect chronic stress (steroids) (15) and physical activity (norepinephrine) (16) and are, therefore, not as indicative of the response to ATC work as is epinephrine.

Total stress (C_s) and duty-related arousal in these FS specialists rank near those same measurements for their counterparts in low-density ATCT's. The relationship between total operations and epinephrine excretion does not hold, however, for FS specialists. This lack of correspondence is perhaps due to the fact that FSS work is not concerned with the direct control of air traffic.

The findings from the STAI are generally consistent with results obtained from other controller populations in that

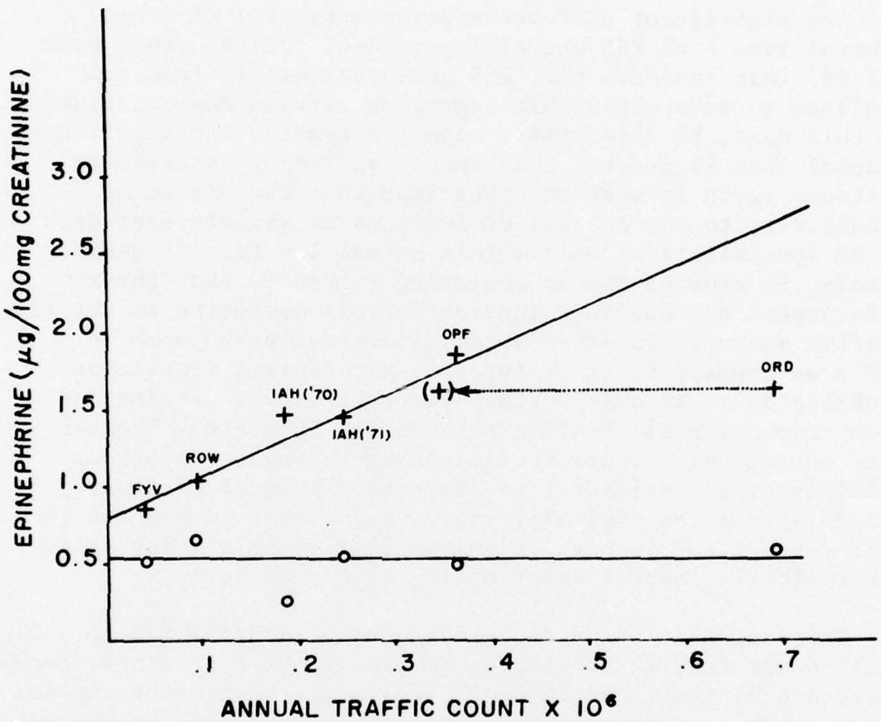

Figure 3. Graph of annual traffic count (in millions of operations) vs. mean urinary excretion levels of epinephrine of controllers at the various facilities. Crosses represent on-duty excretion levels of epinephrine; circles represent corresponding resting levels (ORD represented at actual traffic count and adjusted value (+) as described in text).

ATC and FS specialist work has some apparently moderate arousing quality (11,12,13). As in the previous studies, the absolute level of arousal experienced in undertaking this kind of work is entirely within normal limits.

The significant difference between typical (A-Trait) arousal levels of FSS and ATCT personnel follows other data (17,18) that indicate that FSS personnel differ from controllers to some noticeable degree on certain characteristics. In this case, FS specialists report a tendency to experience arousal that is greater than that reported by controllers, although again it must be emphasized that the degree of sensitivity to the arousal of feelings of anxiety expressed by FS specialists is well within normal limits. It seems likely, in view of the accumulating evidence, that these differences are due to selection factors operating in the air traffic system. In other words, individuals who work in FSS's as opposed to other types of air traffic facilities probably do so because certain characteristics distinguish them from other air traffic personnel. This study suggests that one of these characteristics may be the basic susceptibility of an individual to experience arousal of anxiety. The FS specialist typically shows very normal tendencies in this respect and is high in susceptibility only relative to the typically lower susceptibility of controllers.

The extent to which these data may be generalized to all smaller air traffic facilities remains to be determined, because there are distinct geographical limits to the present sample. However, these data do fit the pattern established by our earlier field studies and provide a perspective from which to assess the impact of air traffic work on the physiological and psychological status of the controller workforce. There is nothing in the present data that suggests unusual reactions in either domain. The data from all the air traffic facilities indicate that epinephrine is the physiological measure most closely associated with traffic count, a finding consistent with the report of Pátkai (19) that epinephrine excretion is related to level of general activation. On the other hand the psychological measures remain relatively uniform across facilities and suggest that air traffic work, no matter what the nature of the facility, has no dramatic impact on the psychological states of controllers. Thus, it is clearly inappropriate to describe air traffic control work, as is commonly

done in the popular press (2,3,4), as an unusually stressful occupation. Popularized accounts of controller stress deal with the exceptional rather than the typical controller or facility. Further, such accounts tend to assume that physiological and psychological changes associated with simple workload effects are undesirable and invariably have long term negative consequences. That assumption is highly questionable, particularly in view of the expressed preference of air traffic controllers for heavy as opposed to light workloads (18).

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